UNITED
NATIONS

E

Economic and Social Council

Distr.
LIMITED

E/CONF.83/L.29
21 January 1991

ENGLISH ONLY

TWELFTH UNITED NATIONS REGIONAL
CARTOGRAPHIC CONFERENCE FOR ASIA
AND THE PACIFIC
Bangkok, 20-28 February 1991
Item 7 (b) of the provisional agenda*

CARTOGRAPHIC DATA RETRIEVAL, ANALYSIS, DEPICTION, PRESENTATION AND PRODUCT GENERATION: DIGITAL DATA BASES

Implementing a cartographic database to enable automation

Paper submitted by the United States of America**

* E/CONF.83/1.

** Prepared by Virginia G. Galvin, National Ocean Service.

91-01916 2089g (E)

/...

READEX FICHE

The Aeronautical Chart Branch (ACB) of the National Ocean Service is beginning to automate the production of some of its charts. The transformation of the production process is an ongoing effort, depending on human considerations and technical factors for success. Currently, production techniques for ACB's products range from traditional manual compilation, engraving, and stick-up to the use of various levels of computer-assisted cartographic tools. Each chart series, with its standard scale, complexity of feature representation, revision cycle, and other characteristics, poses more or less of a challenge in the process of automation.

This paper describes the extent of current automation at ACB and evaluates the feasibility of introducing further automated solutions with regard to various types of charts. By implementing a cartographic database, using a commercially available relational database management system, increased efficiency and flexibility can be realized in the production of a significant number of charts. The paper summarizes the concepts that define a cartographic database and how these concepts serve to resolve problems of redundancy in the revision of charts, increase flexibility in the creation of new products, and enable the automatic flow of cartographic information from the database to the digital chart product.

Finally, the paper presents an overview of the operation of a commercial cartographic database developed for production of aeronautical charts by the Intergraph Corporation. It describes the software components of the Intergraph Aeronautical Charting System (IACS) to be installed by ACB and provides a scenario of the cartographer's interaction with the system, emphasizing the expansion of his responsibilities in controlling the automated compilation process.

IMPLEMENTING A CARTOGRAPHIC DATABASE TO ENABLE AUTOMATION

As a result of four years of aggressive acquisition and development of new hardware and software systems, the Aeronautical Chart Branch (ACB) is ready to implement state-of-the-art cartographic automation. Expanding the use of the computer to assist its traditional cartographic compilation and production methods throughout this period of development, the ACB can now take the next step--linking its volatile databases of aeronautical information directly to the production of digital maps. By doing so, ACB will position itself to automate the physical production of feature negatives and many aspects of the compilation process itself. Benefits accruing to ACB from the automation of these processes would be significant.

Expediting the logistics of maintaining more than 8,000 charts, most subject to revision every 56 days, automation will permit less rigid scheduling and coordination. By eliminating the scribing or stick-up of feature overlays from the production cycle of many charts, automation will also eliminate much of the present dependence on contractor turnaround to complete the cycle. Beyond its cost-effectiveness, automation will serve ACB by enabling it to satisfy growing demands for cartographic digital interfaces from other organizations and from consumers.

Since the success of the automation depends on an understanding of what is being automated, the report will review the traditional, manual techniques currently being used. The report will then trace the initial progress already made toward automation and will describe what further steps remain to be taken to develop a more fully automated system. Methods being implemented by other cartographic organizations approaching automation will be presented to provide a sense of the state-of-the-art. Finally, the report will deal specifically with the Intergraph Aeronautical Charting System--the next phase in ACB's ongoing efforts to automate the production of aeronautical charts.

Cartographers now access numerous hard-copy source documents, including notices, reference manuals, and existing maps, in the process of compiling a chart. Some hard-copy source material is provided them by the Aeronautical Information Section in the form of computer generated listings, calculations, and schematic plots. Painstakingly, manually transferring feature information from these source documents, properly positioning and symbolizing it, the compiler creates a hard-copy "standard", the annotated map manuscript used by contract agency technicians to create or revise the stable plastic film feature overlays that the basemap comprises. Increasingly, as ACB has expanded its aeronautical

information database, the cartographer has used feature data derived from its files as input to computer graphics programs that produce quality-control plots against which the manually compiled map standard may be checked. Only rarely, however, can a computer generated plot be used to produce a feature negative directly.

The compiled map standards and the basemaps produced from these standards exist in purely physical form. Considering the collection of basemaps for all of ACB's published charts to represent a physical (or analog) "database" is useful. Such a "database," however, whether in digital or analog form, remains a discrete collection of maps. Having no unifying relationship between its components, it will not serve as a database of map information from which full automation can proceed. Nonetheless, by converting some of the maps from analog to digital format, ACB has accomplished considerable automation of certain elements of the production process.

The first step toward automation was taken in 1987 with the decision to convert more than 2,000 Radar Video Maps (RVMs) into digital format. The RVMs are not published but are produced as photonegatives, reduced, and ultimately projected on the video screens of Airport Surveillance Radar equipment. Besides being atypical of ACB's chart products in form, they differ significantly in specification of their content and are unique in having only one feature negative. The specification of feature presentation on an RVM is not standard across the map series, but varies according to the needs of the particular air traffic control center requesting the map. The area of chart coverage is limited and the presentation of features simplified, so that a cartographer familiar with the operation of the graphics workstation can digitize an existing RVM in 4 to 8 hours (Bolton and Hoover 9).

In producing the digital maps, cartographers have predictably found the operation of the Intergraph workstations and the application of Intergraph's graphic software--Interactive Graphic Design System (IGDS) and World Mapping System (WMS)--straightforward--"a nearly direct translation of existing manual operations to the computer" (Calkins and Marble 105). By letting cartographers create the RVM basemaps digitally, ACB has enabled automation of the production of the photonegative. The digital compilation has replaced both the hard-copy standard previously used to specify the engraving of the basemap, and the engraved basemap itself. The photonegative is now produced directly from the digital chart and is plotted on-site with a high-precision, Gerber photo-plotter. The manual engraving procedure, with its

lengthy turnaround time, has been completely eliminated, reducing the time required for revision or creation of an RVM from several weeks to a week or even days (Bolton and Hoover 10).

Recently ACB has begun to widen its application of the Intergraph system to produce digital charts of greater complexity. Four new charts of the Enroute Low Chart Series have been created. The workstations, each with a capacity to represent 63 separate design file overlays, have easily managed the task of separating the features of the digital basemaps. As with the RVMs, the creation of the new Enroute Low Alaska charts was mostly accomplished interactively by cartographers at the workstations using computer assisted methods analogous to manual techniques.

Because the products of the compilation process for these charts were themselves digital files, other digital files could often be directly incorporated into the compilation, bypassing the traditional manual transfer of information from hard-copy source documents (Thornburg). Geographic coordinates of features maintained in ACB's general aeronautical database, CONDOR, for example, were extracted into digital files in a separate process. At the workstation, using WMS, the cartographer was able to access these files directly and use them to place fully symbolized features in the digital maps. Although the Alaska Enroute charts were not, in fact, used to produce photographic feature overlays directly, the potential for doing so was clearly demonstrated (Thornburg).

ACB has used digital maps to eliminate the need to manually engrave or stick-up features on basemap overlays and even to make the compilation process itself more efficient. It now plans to establish a unified cartographic database from which dynamically linked digital charts can be derived and maintained and, thus, to achieve the full potential of cartographic automation (Bundock 294-295).

Considering ACB's collection of analog and digital basemaps as a "database" of map information, it is apparent that such a collection is far from unified. A feature occurring on more than one chart is represented more than once in the "database", and may be represented differently in each "database" occurrence. The same real, geographic feature, for example, appearing on both an Instrument Approach Procedure (IAP) chart and an Enroute chart may be shown on each chart at a different scale. Revision of the feature entails two separate basemap revisions, with each revision varying according to the scaled representation of the feature. The symbol for another feature, such as an airport, may be shown in blue or brown on an Enroute chart and in black on a

Standard Terminal Arrival (STAR) chart. On a Sectional chart, the same airport feature may be shown by a different symbol entirely--again, necessitating more than one revision and more than one type of revision.

Developing a unified cartographic database (CDB) dynamically linked to the digital chart products derived from it, will help eliminate the problem of multiple revisions for a single feature. Any change, addition, or deletion to the CDB will automatically propagate from the database to the individual charts derived from the database on which the feature occurs. The revision of each feature occurrence will be in accordance with the defined specifications for scale and symbolization of the feature for the chart containing the occurrence.

These cartographic specifications, and others, will themselves be part of the CDB, and, by their inclusion in that database, will link the CDB to each of the digital charts. A CDB can be created using one of the commercially available database management systems (DBMS):

> Many of the above problems can be solved using any one of a number of commercially available database management systems. Hence it is proposed that a DBMS be utilized to manage not only the geographic attribute data, but also the cartographic data. The data defining the cartographic entities to be displayed can be managed within a DBMS in much the same way as any other data. (Bundock 295)

While the revision process will become more efficient with such a system, the design process will also become more flexible. New charts, at larger scales, representing portions of existing maps are sometimes required to relieve feature congestion in the smaller scale existing maps. Projects such as the redesign of the H3 Northeast Enroute chart and creation of the H6 Eastcoast Enroute chart would be accomplished more easily and quickly since feature data would exist in the CDB "seamlessly", independently of any chart boundaries, and could be extracted to fit any chart configuration at any scale.

Other organizations attempting cartographic automation based on these principles include the Nautical Chart Branch of the National Ocean Survey, and Jeppesen Sanderson, Inc., a private aviation chart producer.

The Nautical Chart Branch (NCB) is currently developing the prototype for its Automated Nautical Charting System (ANCS II).

Intergraph Corporation is providing NCB with workstations, graphics software, and a cartographic database design based on the commercially available relational DBMS, Oracle (Poltivolo).

The NCB will maintain two databases. The Nautical Information Data Base, a general purpose database, will be used to derive and maintain the separate Chart Graphics Data Base (Smith 1374).

A private, commercial organization, Jeppesen Sanderson, Inc., has used Intergraph systems in its production of IAPs and Enroute charts for several years. Its current software system, now providing many automated capabilities, will soon be superseded by Intergraph's recently developed, third generation aeronautical charting product, Intergraph Aeronautical Charting System--IACS (Kelly). The production process now, as demonstrated in their promotional videotape (Jeppesen Sanderson, Inc.), involves the transfer of updated aeronautical information from a general purpose database maintained on a VAX 11/750 to an Intergraph processing system dedicated to the maintenance of the digital charts. Updates applying to each chart are interactively validated or rejected by compilers at workstations connected to the Intergraph processor. The compilers interpret the update status of each chart feature on the basis of its displayed color, with red indicating deletion from the database, yellow indicating a change, etc. Once all database generated revisions have been either validated, modified, or rejected, a hard-copy, electrostatic print is made of the workstation display on a Versatec V80 plotter and given to another compiler for quality-control review. Finally, a copy of the digital chart is put on magnetic tape and transferred to a Scitex laser-plotter system which uses the digital chart to produce high-resolution film positives or negatives suitable for reproduction.

To achieve its automation goals as efficiently as possible, ACB also plans to install the Intergrapn Aeronautical Charting System. IACS uses existing hardware and software, including Ingres, WMS, and IGDS. Ingres has already been installed for other purposes and is being developed to provide a general aeronautical information database, similar to CONDOR but more powerful and flexible. This database will remain distinct from the cartographic database but eventually may be used to update it. With Ingres, IGDS, and WMS software currently operational, no great financial outlay will be required to provide the initial environment in which to develop prototype applications of IACS.

ACB's cartographers have already used WMS and IGDS software at the workstations and will be familiar with these components of the IACS system. They will not have had experience with Ingres,

the relational database that constitutes the third component of the IACS system. Intergraph, however, has designed a user-friendly, form-driven menu to the Ingres cartographic database that will make it more accessible (Intergraph Corp. 1:7-9).

Initially, both the features depicted in the charts and the specifications defining each chart will need to be established in the cartographic database. Aeronautical Chart Automation Section cartographers and computer specialists will work closely with cartographers in other Sections to accomplish this. Much feature data in the charts may need to be digitized manually in the WMS environment. Other feature data used to populate the database may be derived from existing CONDOR files. Chart specifications will need to be entered interactively through IACS's forms-driven interface to Ingres.

After the CDB has been populated, the cartographer will be able to generate charts from it and maintain digital charts previously generated. Beyond the need to define new chart specifications, there will be little difference between the procedures for creating a new chart or for maintaining an existing chart with IACS (Intergraph Corp. 6:1-11).

In maintaining a chart, the cartographer will receive an IACS generated report identifying any changes to it subsequent to any update of the CDB. Whenever the decision is made to compile these pending changes to the chart, the compiler activates IACS, identifying the chart and initiating the batch extraction of updated feature data to be applied to it from the CDB. On completion of the extraction process, the compiler initiates another IACS process to automatically symbolize the extracted feature data according to the specifications of the chart. The symbolized, updated data is then automatically incorporated into the digital chart. At the workstation, the cartographer makes final judgements on the disposition of any of the displayed pending changes. Here too, the cartographer's judgement must be exercised in cleaning up the chart to final standards.

IACS is not an "expert system." Such systems have not developed sufficiently to replace human skill and knowledge in the field of cartography (Gallant 386). Many situations will arise requiring deletion, displacement, or other modification of features included automatically in the digital compilation. Considering the critical application for which the aeronautical chart product is designed, the need for human validation of changes propagated automatically will be of increased, not diminished importance at ACB.

Chart series considered as candidates for IACS need to be evaluated for ease of original conversion and for adequacy of feature coverage in the general aeronautical database to be used to update the CDB. Since the demands placed on graphics workstations and photoscribing equipment will increase with the automation of more charts, the time required to produce charts of varying complexity using these limited resources must also be considered in the cost-effectiveness equation. The production of Radar Video Maps has already undergone partial automation. At some point, these maps may be considered candidates for IACS. Priority now, however, should be given to commercial charts produced on short, regular cycles. The cost-effectiveness of pipelining the flow of information from database to chart will be greater the more frequently and extensively the chart must be revised.

Sectional and Terminal Area Charts are revised every 6 months and are rich in topographic feature detail. The topographic features, derived primarily from U.S. Geological Survey 7 1/2-minute quadrangle maps, are not supported by the aeronautical database, making the full automation of these series unlikely. In the future, however, it may prove feasible to maintain aeronautical feature overlays for these charts using an automated system while continuing to maintain the topographic overlays of the basemaps manually (Tamm-Daniels, Cooper, and McCollough 514).

The primary candidates for IACS automation are the Enroute and IAP charts. These chart series are maintained on 56 day cycles. Presentation of topographic feature data is extremely limited. The Enroute charts are the more complex charts, consisting of twenty or more feature overlays. The monochromatic IAP charts have only three overlays, cover smaller geographic areas, and are physically smaller (about 5 x 7 inches). Photoscribing new feature negatives and reviewing new chart prints for charts of the size and complexity of the Enroute charts will be time-consuming. To reduce demands on equipment and personnel, photoscribing of new negatives could be limited by continuing to make minor modifications to film overlays by hand after having first established these modifications in the digital map through IACS.

The charts that will most easily be adapted to IACS are the IAPs. In the initial conversion process, these charts will probably require about the same amount of time to digitize as the RVMs. With few overlays, small in size, and limited in complexity and coverage, they could be completely photoscribed and reviewed every 56 days. Their short revision cycle takes full advantage

of the automated flow of update information from the CDB. The cost benefits from automation of the IAPs may even prove greater than those shown for the RVM series because of the greater frequency of revision and greater degree of automated compilation that will be introduced for the IAPs.

Development of automated cartographic production, beginning with the conversion of the IAP Chart Series, will be a cooperative endeavor involving the efforts of both cartographers and computer specialists. Once established, IACS will not eliminate the role of the cartographer from the compilation process. Instead, that role will expand to include new responsibilities in the operation and monitoring of the system.

WORKS CITED

Bolton, Ronald M., and Russel A. Hoover. "Automated Radar Video Map Production at NOS." Aeronautical Charting Division, National Ocean Service, National Oceanic and Atmospheric Administration. Oct. 1987.

Bundock, M.S. "An Integrated DBMS Approach to Geographical Information Systems." Auto-Carto 8 Proceedings, Baltimore, MD. 29 Mar. to 3 Apr. 1987. Falls Church: ASPRS/ACSM, 1987, 292-301.

Calkins, Hugh W., and Duane F. Marble. "The Transition To Automated Production Cartography: Design Of The Master Cartographic Database." The American Cartographer 14.2 (1987): 105-119.

Gallant, David G. "The Misguided Evolution of Future Mapping Technology." Auto-Carto 8 Proceedings, Baltimore, MD. 29 Mar. to 3 Apr. 1987. Falls Church: ASPRS/ACSM, 1987.

Intergraph Corp. Intergraph Aeronautical Charting System (IACS) Reference Manual. Huntsville: Intergraph Corp., 1989.

Jeppesen Sanderson, Inc. N.t. (Promotional material on automated chart production), n.d., videotape.

Kelly, David W. Software Scientist, Intergraph Corporation. Telephone interview, 26 Feb. 1990.

Poltivolo, David. Graphics Manager, Nautical Chart Branch, National Ocean Survey, National Oceanic And Atmospheric Administration. Personal interview, 26 Mar. 1990.

Smith, Norman D. "Automated Nautical Data and Charting Development." Oceans' 88 Proceedings 4. New York: IEEE, 1988, 1374-1378.

Tamm-Daniels, Frederick L., John R. Cooper, Jr., and Major C.R. McCollough. "The Automated Revision of Tennessee Valley Topographic 1:24,000 Quadrangles." Auto-Carto 7 Proceedings, Washington, D.C. 11 Mar. to 14 Mar. 1985. Falls Church: ASP/ACSM, 1985, 514-522.

Thornburg, Tim. Cartographer, Aeronautical Chart Automation Section, Aeronautical Charting Division, National Ocean Survey, National Oceanic And Atmospheric Administration. 2 Apr. 1990.

APPENDIX A

GLOSSARY OF TERMS

Analog - Representing data by physical quantities. For example, the geographic distance between two locations is represented as a scaled analog distance on a map.

Basemap - The collection of photographic, engraved, or digital feature overlays that are used to create the photographic plates for lithographic reproduction of a map.

Batch processing - Computer processing occurring independently of any current session at the computer terminal, a background job.

Chart - A map used in navigation.

Compilation - The process of assembling, organizing, and laying out data to create or revise a map, or the layout manuscript itself.

Compiler - The cartographer who makes a compilation.

Database - A collection of data organized for retrieval as useful information.

Digital - Defined by numerical units. For example, computer data is defined by binary (0's and 1's) digital data.

Digitize - To convert to digital form. For example, at a graphics workstation, an analog map can be converted into a digital file.

Enroute Chart - Aeronautical chart that is used by pilots to navigate with information obtained from instrument readings and radio contact.

Expert system - A computer system that makes complicated decisions to resolve certain problems based on logic developed by human experts.

Feature - A manmade or natural phenomenon depicted on a map. For example, the prescribed flight path between two cities is an aeronautical feature, while the cities themselves are topographic features.

File - An organization of digital data created by and accessed by a computer.

Graphics workstation - A type of computer terminal that allows digital data to be created, modified, and displayed as visual patterns. The techniques used to create or modify the digital graphic display appear to the user to be similar to manual graphic techniques.

Instrument Approach Procedure Chart - Aeronautical Chart that is used by pilots making an approach to landing based on instrument readings and radio contact.

Interactive processing - Computer processing that requires connection of the user to a computer through a session at a terminal.

Laser-plotter - A plotter that uses a laser beam to expose a photographic negative.

Overlay - The collection of all map features of a similar type on a sheet of semi-transparent plastic film, or the collection of all such features on a transparent, electronic, digital display. The set of layered plastic film sheets or digital displays for all the features shown on the map is the "basemap".

Photo-plotter - A plotter that uses a light beam to expose a photographic negative.

Photoscribe - To expose a photographic negative using a laser-plotter or photo-plotter.

Plot - To use a file of digital information as input to a plotter to produce lines on paper, photographic negatives, or other material.

Plotter - The output device that translates a digital graphics file into a visual design on paper or other material.

Processor - A computer.

Relational database - A type of digital database that depends on existing similarities of data to find relationships between different subsets of the data.

Scribing - Engraving of lines on a coated sheet of plastic film.

Sectional Chart- Aeronautical chart used by pilots navigating by topographic landmarks.

Stick-up - Attaching pre-printed symbols, lines, and text to feature overlay sheets.

Symbol - A graphic design used to represent a feature on a map.

Symbolize - To represent a feature on a map using a symbol.

Terminal Area Chart - Aeronautical chart covering the geographic area of an airport terminal, similar to a Sectional Chart but larger in scale.

Topographic- Pertaining to the configuration of a surface, such as the surface of the earth.

UNITED
NATIONS

E

Economic and Social Council

Distr.
LIMITED

E/CONF.83/L.30
21 January 1991

ENGLISH ONLY

TWELFTH UNITED NATIONS REGIONAL
CARTOGRAPHIC CONFERENCE FOR
ASIA AND THE PACIFIC
Bangkok, 20-28 February 1991
Item 7 (e) of the provisional agenda*

CARTOGRAPHIC DATA RETRIEVAL, ANALYSIS, DEPICTION, PRESENTATION AND PRODUCT GENERATION: SPECIFICATIONS AND STANDARDS

Mapping, charting and geodetic standardization activities within the United States Department of Defense

Paper submitted by the United States of America**

---

* E/CONF.83/1.

** Prepared by Mel Wagner, Defense Mapping Agency.

The Defense Mapping Agency, as the responsible agency within the U.S. Department of Defense for Mapping Charting and Geodetic Technology, has undertaken a comprehensive program of standardization. This program addresses the user environment and utility software including standards for the exchange, display and manipulation of digital mapping, charting, and geodetic information for U.S. Department of Defense users. This paper describes current Defense Mapping Agency System Center initiatives within the standards program.

Introduction

The Defense Mapping Agency, as the responsible agency within the U.S. Department of Defense for Mapping, Charting, and Geodetic Technology, has established a comprehensive program of standardization. The goal of this research and development initiative is to develop a comprehensive suite of standards for the exchange, manipulation and display of digital data. The purposes of the program are to assure the compatibility and interoperability of digital mapping, charting, and geodesy data bases supporting a wide variety of simulators, command and control, navigation and weapon systems; to assure that data from different sources and from different collection techniques can be combined, processed and displayed in a common geographic reference frame; and to assure that two users performing the same or similar functions will get comparable results.

New Products on Compact Disc-Read Only Memory (CD-ROM)

There are a number of current R&D projects which support these goals. For example, in 1989 Defense Mapping Agency produced 460 CD-ROMs containing ARC Digitized Raster Graphic products, including rasterized versions of Operational Navigation Charts, Tactical Pilotage Charts and 1:50,000 scale Topographic Line Maps. 850 new CD-ROMs were produced in 1990. Our current schedule is to produce 1000 new CD-ROMs per year. World Vector Shoreline, formerly available only on magnetic tape, is now available on CD-ROM. A production capability for Digital Terrain Elevation Data has been established. All available Digital Terrain Elevation Data should be published on CD-ROM by April of 1990. In 1991, we intend to prototype on CD-ROM, the Electronic Chart Update Manual, Tactical Terrain Data, Interim Terrain Data, and Digital Navigation Publications.

Digital Products Study

In May 1990, the Defense Mapping Agency Deputy Director for Management and Technology commissioned the "Defense Mapping Agency Digital Products Study" to look at Defense Mapping Agency's standardization activities. The goal of this study was to provide a "framework for development of mapping, charting, and geodetic standards". Phase 2 of this study, begun in November and expected to last for 3 months, will provide an implementation plan for execution of this framework within an integrated environment. The scope of this study addresses U.S. Department of Defense weapons and system requirements, an assessment of commercial geographic information systems capabilities, data compression, media, ongoing map, chart, imagery and formatted text projects as well as the mapping, charting, and geodesy needs of the intelligence community. The framework that evolved from this study is a mapping, charting, and geodesy hierarchy of standards. At the very top of this architecture is the "Environment Level". Within

this level are the protocols which enable the algorithms and software at the lower levels to operate within the users environment. Included will be such things as standard operating system environments, standard query languages, presentation manager interfaces and graphics interfaces. This level represents standard platforms and operating system environments such as VAX, MacIntosh, PC and Sun workstations, standard languages such as FORTRAN and C, presentation managers such as X-Windows and standard query languages such as SQL. The Defense Mapping Agency will not drive these standards but we must insure that lower level standards which are developed are compatible with these standard environments.

The "Exploitation Level" will contain user oriented standard algorithms for such things as datum transformations, grid and projection generation, coordinate conversions, thinning and generalization, contouring, paneling and merging. This level is very important, for it is here where Defense Mapping Agency can have a tremendous impact. We must provide not only standard algorithms and software, but guidance on the proper applications, expected accuracies and selection criteria to choose the proper algorithms to satisfy user specific applications.

The "Data Directory Level" contains global information common across all product forms: tiling, indexing and cataloging schemes, recording history, spatial referencing schemes, accuracy, currency and legend information, as well as indices to aid the user in rapid access techniques.

At the "Product Level", the content, extent (coverage) and accuracy of specific products will be defined. Product Level standards also include delineation rules, capture and inclusion conditions, relations, procedural constructs and symbolization rules.

The "Data Dictionary Level" defines the spatial data structure (i.e. raster versus vector), and the feature coding scheme (i.e. glossary and lists of features and their attributes).

The "Format Level" describes the manner in which the physical organization of data is determined. For records, fields and sub-fields, the format defines the use of fixed versus variable lengths; the use of tags and delimiters versus constant position; the use of ASCII versus binary character coding; and the imbedding of the format description within the data set versus separate documentation.

The "Media Level" standards describe the volume labelling and physical characteristics of the transport media (i.e. magnetic tape, CD-ROM, etc.). Defense Mapping Agency will not influence standards at this level but will adopt pertinent industry standards such as ISO 9660 for volume labeling and Philips Yellow Book for the physical characteristics of CD-ROM.

Digital Chart of the World

Defense Mapping Agency's flagship effort for the development of vector product standards is called Digital Chart of the World. The goals of this initiative are: the development of exchange standards for all Defense Mapping Agency vector products; the demonstration of those exchange standards on a broad range of prototypes; development of software to display and manipulate data using the standards; and the production of a 1:1 Million scale product, suitable for geographic information systems applications. The Digital Chart of the World product is based on the existing 1:1 Million scale Operational Navigaiton Charts. It will be topologically structured, thematically separated and organized relationally. Digital Chart of the World will be distributed on CD-ROM. The final product will be available at the end of 1991.

Utility Software Development

Several initiatives are underway to assist the user in the import, display and manipulation of digital mapping, charting and geodetic information under the mapping, charting and geodesy utility software development program. The Common User Interface project will standardize the look and feel of interactive menus and standardize terminology used.

The Software Design project will establish conventions for the design, documentation and development of mapping, charting, and geodesy utility software.

The goal of the Symbol Development and Display project is to establish a mechanism for creation and exchange of standardized symbol libraries for display in a softcopy environment.

The current U.S. Department of Defense Glossary of Mapping, Charting, and Geodetic terms is being updated to include definitions of digital and geographic information systems terminology applicable to Defense Mapping Agency products.

A Handbook on Datum Transformations, Generation of Grids and Projections and Coordinate Conversions has been circulated for service review. This handbook provides guidance to users on selection of appropriate algorithms, expected accuracies and performance characteristics. A follow up to this project is an effort to establish U.S. Military Standards software employing the guidance of the handbook.

An Operations Concept for a library of utility software is under development which will identify how the software will be maintained and distributed, how configuration management will be performed and how information on available software will provided to the users.

1991 Research and Development Initiatives

All of the previous initiatives represent current activities. The following activities represent new starts for 1991 and beyond.

The goal of the Digital Map Data Comparison initiative is to demonstrate the proper application and uses of machine readable products. These demonstrations will highlight the differences, advantages, disadvantages and capabilities of Defense Mapping Agency vector, raster and video products. The Digital Products Study, mentioned earlier, identified a number of different compression techniques suitable for use on Defense Mapping Agency raster, vector and formatted text products. The study concluded that selection of a single compression methodology could not be done without a detailed analytical evaluation to test both the metric and visual effects of compression. The services have been invited to participate in this compression study. At the conclusion of the study, a single compression technique will be selected (for each product form) and applied to Defense Mapping Agency products.

Development of standards which describe the structure, format, content, etc. of new digital products will continue. Transition plans for the application of these standards to traditional Defense Mapping Agency digital vector, raster and formatted text products will be developed.

Efforts will also continue in the development of demonstration and display, translation and utility software for the import, display and manipulation of mapping, charting and geodesy data in the typical user environment.

The Defense Mapping Agency will also investigate the use of new media technologies, including Write Once Read Many, Very Large Data Storage, rewritable optical media, Videodisc and 8MM cassette.

We will also continue our support, both financially and through participation, to joint efforts within U.S. Department of Defense, other national and international agencies and academia. Some of these include: the Digital Geographic Information Working Group, National Center for Geographic Information Analysis, the Federal Geographic Data Committee (formerly Federal Interagency Coordinating Committee on Digital Cartography), National Science Foundation, National Institute of Science and Technology and the International Geodetic Symposium on Global Positioning Satellite.

Conclusion

In summary, Defense Mapping Agency has been involved in digital product standardization activities for more than a year. A study identifying and addressing major mapping, charting and geodesy issues concerning production, a hierarchy of mapping, charting and geodesy standards, compression, decompression, utility software, computer readable media, packaging and distribution, digital map displays, advanced products concepts and rapid prototyping capabilities will make important recommendations on the optimum uses of Defense Mapping Agency's digital products. This information will support our participation and coordination with national and international standardization organizations.

For further information of Defense Mapping Agency's Data Standardization program, contact:

Director
Defense Mapping Agency
ATTN: PRS (Mr. Frey)
8613 Lee Highway
Fairfax, Virginia 22031-2137
Telephone: (703) 285-9238

or

Director
Defense Mapping Agency Systems Center
ATTN: SGC (Mr. Wagner)
8613 Lee Highway
Fairfax, Virginia 22031-2138
Telephone: (703) 285-9257

UNITED
NATIONS

E

Economic and Social Council

Distr.
LIMITED

E/CONF.83/L.31
21 January 1991

ENGLISH ONLY

TWELFTH UNITED NATIONS REGIONAL CARTOGRAPHIC
CONFERENCE FOR ASIA AND THE PACIFIC
Bangkok, 20-28 February 1991
Item 5 (a) of the provisional agenda*

CARTOGRAPHIC DATA ACQUISITION AND SUPPORTING ACTIVITIES: CONVENTIONAL AND SATELLITE GEODESY

World geodetic system 1984: A modern and accurate global reference frame

Paper submitted by the Defense Mapping Agency**

---

* E/CONF.83/1.

** Prepared by Muneendra Kumar, Defense Mapping Agency.

The Defense Mapping Agency has developed the World Geodetic System (WGS) 1964; it is a state-of-the-art global geodetic reference system based on the use of data, techniques, and technology available within DMA through early 1984 and replaces its predecessor WGS 72. The WGS 84 reference frame, Earth Gravitational Model, geoid, and datum transformation parameters (with the local datums) are more accurate and relate more datums (83 compared to 27 for WGS 72).

These improvements can be translated into more accurate maps and charts, geodetic positioning, geoidal heights, improved satellite orbits, and the capability to relate many more local datums worldwide to a unifieid system.

Introduction

In this complex world where numerous Mapping, Charting, Geodetic , and digital products are defined in various local and/or regional geodetic datums, it becomes a straight forward requirement to simplify MC&G complexity by referencing all the products to a common reference frame globally. With this need in mind, the Defense Mapping Agency (DMA) has been actively involved since 1960 in the development of World Geodetic System (WGS). To date, four such systems, viz., WGS 60, WGS 66, WGS 72, and WGS 84, each successively more accurate, have been developed.

The latest WGS 84 represents DMA's state-of-the-art modeling of the earth from a geometric, geodetic, and gravitational standpoint using data, techniques, and technology available through early 1984.

The Reference Frame

The origin of the WGS 84 reference frame is the earth's center of mass and the Z- and X-axes are identical to the Conventional Terrestrial System as defined by the Bureau International de l'Heure for the epoch 1984.0 (Figure 1). This frame constitutes a mean or standard earth rotating at a constant rate (ω) around an average astronomic pole fixed in time.

In turn, the WGS 84 reference frame is related to an Instantaneous Terrestrial System and a Conventional Inertial System:

$$\text{WGS 84 (CTS)} = [A]\ [B]\ [C]\ [D]\ \text{CIS} \qquad (1)$$

Origin - Earth's center of mass

Z-Axis = Parallel to the direction of the Conventional Terrestrial Pole for polar motion, as defined by the Bureau I International de L'Heure on the basis of the coordinates adopted for the Bureau International de L'Heure stations.

X-Axis = Intersection of the WGS 84 Reference Meridian Plane and the plane of the Conventional Terrestrial Pole's Equator, the Reference Meridian being parallel to the Zero Meridian defined by the Bureau International de L'Heure on the basis of the coordinates adopted for the Bureau International de L'Heure stations.

Y-Axis = Completes a right-handed, earth centered, earth fixed orthogonal coordinate system, measured in the plane of the Conventional Terrestrial Pole Equator, 90° East of the X-Axis.

BIH-Defined Conventional Terrestrial Pole (1984.0)

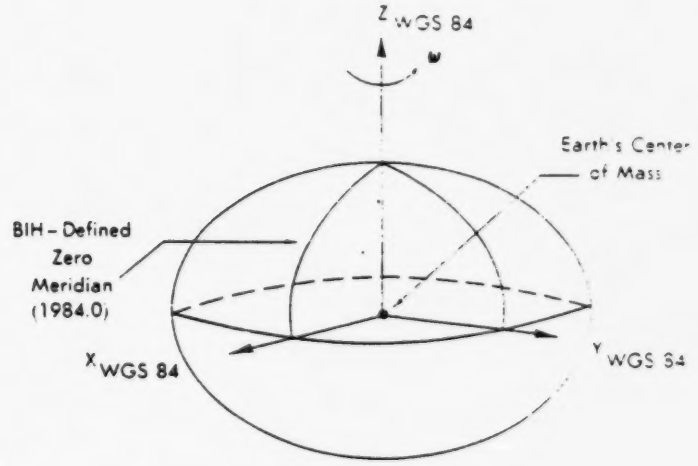

Figure 1. World Geodetic System 1984 Reference Frame.

where the rotation matrices for polar motion [A] sidereal time [B], nutation LC], and precession [D] are from the FK 5 System referenced to Epoch J2000.0.

For practical realization, the WGS 84 reference frame or coordinate system was defined by suitably modifying the NSWC 9Z-2 coordinate system of the Navy Navigation Satellite System. This modification consisted of the removal of biases in the origin, scale, and longitude definition of the Doppler system and is defined as:

$$Z(\text{WGS 84}) = Z(\text{NSWC 9Z-2}) + 4.5 \text{ meters} \quad (2)$$

$$S(\text{WGS 84}) = S(\text{NSWC 9Z-2}) - 0.6 \text{ ppm} \quad (3)$$

$$\lambda(\text{WGS 84}) = \lambda(\text{NSWC 9Z-2}) + 0.814'' \quad (4)$$

In the above relationships, Equations 2-4 refer to the Z-axis bias, scale correction, and longitudinal bias in the definition of the prime meridian, respectively, and the WGS 84, thus achieved, is coincident with the Bureau International de L'Heure-defined CTS[1].

The Defining Parameters and Associated Constants

In geodetic considerations, three different surfaces or earth figures are normally involved and used. In addition to the earth's actual physical surface, the other two include a geometric (or mathematical) reference surface, the ellipsoid, and an equipotential surface, the geoid.

In determining the WGS 84 Ellipsoid and its associated defining parameters, the WGS 84 Development Committee decided to adopt the International Union of Geodesy and Geophysics defined Geodetic Reference System 1980 as its reference.

The WGS 84 Ellipsoid, as an integral component of the system for the earth's geometric figure and theoretical gravity definition, is a geocentric, equipotential, ellipsoid of revolution; Table 1 lists the four defining parameters adopted from the Geodetic Reference System 80[2], except for one minor exception. The WGS 84 defines C_2 instead of J_2 of Geodetic Reference System 80.

Other associated constants adopted and used in WGS 84 are given in Table 2.

Table 1
WGS 84 Ellipsoid
Four Defining Parameters

Parameters	Notation	Magnitude	Accuracy (1 σ)
Semimajor Axis	a	6378137 m	±2 m
Normalized Second Degree Zonal Harmonic Coefficient of the Gravitational Potential	$\bar{C}_{2,0}$	$-484.16685 \times 10^{-6}$	$\pm 1.30 \times 10^{-9}$
Angular Velocity of the Earth	ω	7292115×10^{-11} rad s^{-1}	$\pm 0.1500 \times 10^{-11}$ rad s^{-1}
The Earth's Gravitational Constant (Mass of Earth's Atmosphere Included)	GM	3986005×10^{8} m^3 s^{-2}	$\pm 0.6 \times 10^{8}$ m^3 s^{-2}
Parameter Values for Special Applications			
The Earth's Gravitational Constant (Mass of Earth's Atmosphere Not Included)	GM′	3986001.5×10^{8} m^3 s^{-2}	$\pm 0.6 \times 10^{8}$ m^3 s^{-2}
Angular Velocity of the Earth (In a Precessing Reference Frame)	ω*	$(7292115.8553 \times 10^{-11} + 4.3 \times 10^{-15} T_U)$ rad s^{-1}	$\pm 0.1500 \times 10^{-11}$ rad s^{-1}

T_U = Julian Centuries From Epoch J2000.0

/...

World Geodetic System 1984

Table 2
Relevant Miscellaneous Constants and Conversion Factors

Constant	Symbol	Numerical Value
Velocity of Light (in a Vacuum)	c	299792458 m s^{-1}
Dynamical Ellipticity	H	1/305.4413
Earth's Angular Velocity [for Satellite Applications; see Equation (3-14), Reference 3.]	ω^*	$(7292115.8553 \times 10^{-11} + 4.3 \times 10^{-15} T_U)$ rad s^{-1}
Universal Constant of Gravitation	G	$6.673 \times 10^{-11} m^3 s^{-2} kg^{-1}$
GM of the Earth's Atmosphere	GM_A	$3.5 \times 10^8 m^3 s^{-2}$
Earth's Gravitational Constant (Excluding the Mass of the Earth's Atmosphere)	GM'	$3986001.5 \times 10^8 m^3 s^{-2}$
Earth's Principal Moments of Inertia (Dynamic Solution)	A	8.0091029×10^{37} kg m^2
	B	8.0092559×10^{37} kg m^2
	C	8.0354872×10^{37} kg m^2

Conversion Factors

1 Meter	= 3.28083333333 US Survey Feet
1 Meter	= 3.28083989501 International Feet
1 International Foot	= 0.3048 Meter (Exact)
1 US Survey Foot	= 1200/3937 Meter (Exact)
1 US Survey Foot	= 0.30480060960 Meter
1 Nautical Mile	= 1852 Meters (Exact)
	= 6076.10333333 US Survey Feet
	= 6076.11548556 International Feet
1 Statute Mile	= 1609.344 Meters (Exact)
	= 5280 International Feet (Exact)

T_U = Julian Centuries from Epoch J2000.0

The Gravity Formula

In many applications, such as the computation of gravity anomalies, theoretical (or normal) gravity (γ) is required as a reference value. Values of γ_Φ in the WGS 84 (for any latitude Φ) can be computed using the closed formula:

$$\gamma_\Phi = \gamma_e \frac{(1 + k \sin^2 \Phi)}{(1 - e^2 \sin^2 \Phi)^{1/2}} \qquad (5)$$

where,

γ_e = normal gravity at the equator

= 978032.67714 mgal

k = 0.00193185138639

e^2 = 0.00669437999013.

The Earth Gravitational Model

The Earth Gravitational Model (EGM) of the WGS 84 is a spherical harmonic expansion of the earth's gravitational potential and is defined complete through degree (n) and order (m) 180, comprising 32,755 coefficients. However, only the coefficients through n = M = 18 are unclassified [3].

Accuracy values are not available for all the WGS 84 EGM coefficients; however, an error covariance matrix is available only for coefficients through n = m = 41, which were determined from the weighted least squares solution

The Geoid

In addition to the earth's geometric surface or figure, the WGS 84 geoid, as the equipotential figure of the earth (also approximated by mean sea level over the oceans), is defined as so many meters above (+ N) or below (- N) the WGS 84 ellipsoid, where "N" is known as geoidal height or undulation.

The worldwide geoidal heights were calculated using the WGS 84 EGM through n = m = 180, and they can also be depicted as a contour chart (showing deviations from the WGS 84 ellipsoid) or as a grid of desired density. Figure 2 shows a worldwide WGS 84 geoid chart developed from a worldwide 1° x 1° grid using the unclassified EGM coefficients through n = m = 18.

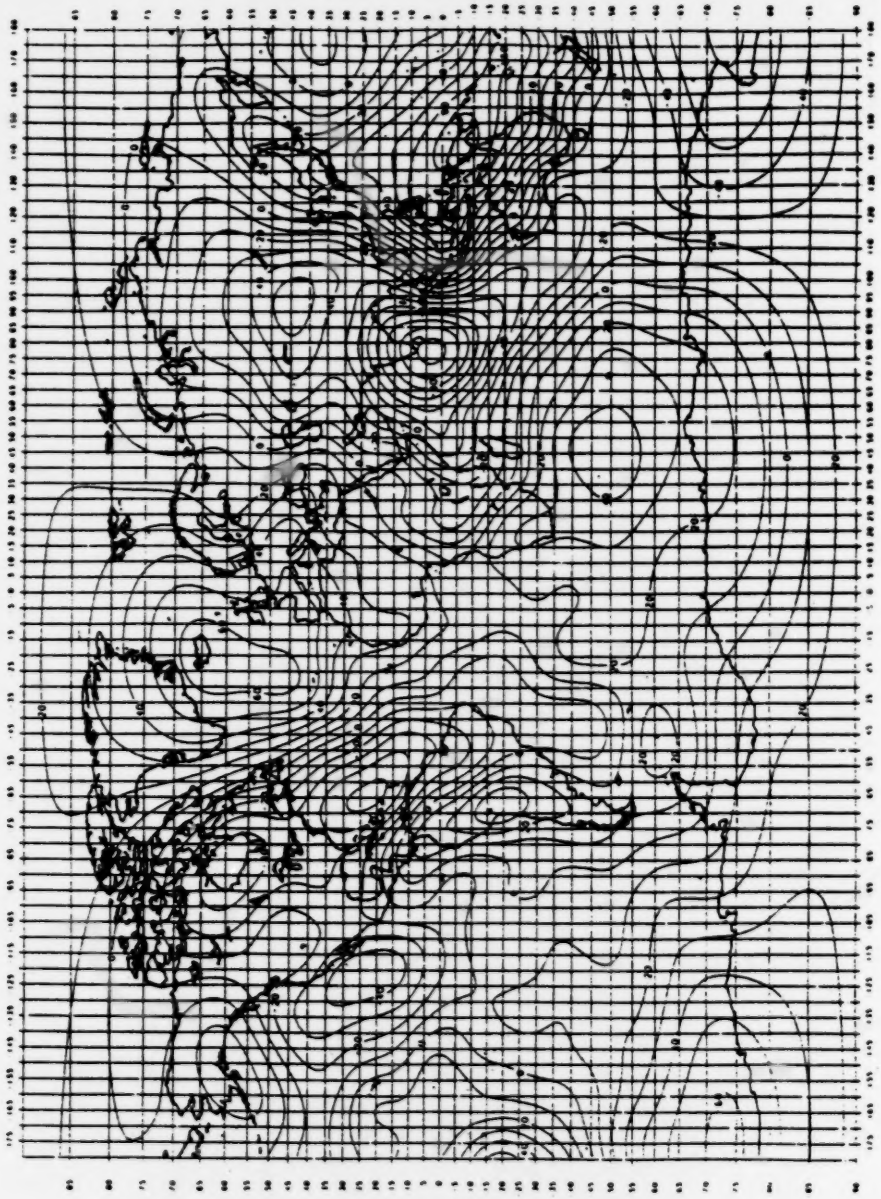

Figure 2. WGS 84 Geoid (n = m = 18 Truncation) Referenced to WGS 84 Ellipsoid ($\overline{\delta C}_{4,0}$, $\overline{\delta C}_{6,0}$, $\overline{\delta C}_{8,0}$, and $\overline{\delta C}_{10,0} \neq 0$; Units = Meters).

The Root Mean Square geoidal height for WGS 84, taken worldwide, is 30.5 meters and the error ranges from plus or minus 2 to plus or minus 6 meters (1 σ). The accuracy of the WGS 84 geoid is better than plus or minus 4 meters over approximately 93% of the globe.

Relationship with Local Geodetic Datums

Counting islands and/or other "astro" datums, the number of local geodetic datums available for mapping, charting, and geodesy requirements and applications exceeds several hundred. If the inherent technical difficulties of dealing with these numerous local datums, each defined with its own specifications and basic limitations, are considered in daily usage, the picture is just too complex and almost chaotic.

Under this bleak scenario, one of the principal purposes of a World Geodetic System is to provide the means whereby these numerous local geodetic datums can be referenced to a common system (or to each other indirectly through extrapolation) and then, WGS can facilitate simplification of the global mapping, charting, and geodesy problem.

To achieve the referencing of a local datum to WGS 84, one major requirement is to have well-distributed control points common to both the systems. DMA maintains a worldwide database of Navy Navigation Satellite System Doppler station. A search of this database produced 1591 good quality Doppler stations, which also had coordinates defined in the local datum of the area.

These 1591 Doppler stations cover 83 local geodetic datums spread out over all the six continents [3]. From a high of 405 Doppler stations common with the North American Datum 1927 in the contiguous United States, there are 29 datums with only one common station. This limitation of not having any check station thus affects about 35% (29 of 83) of the datums.

As the local geodetic datums are generally defined only horizontally and provide mean sea level (msl) heights from separately defined vertical datums the geodetic heights in the local datum (H_{LD}), required to compute datum transformation parameters, were generated using the following equation:

$$H_{LD} \approx h_{msl} + N_{LD} \qquad (6)$$

In the above equation, the local datum geoidal heights (NLD) were obtained by appropriate transformation from the WGS 84 geoidal heights. These local geoids are absolute (contrary to the relative astro-geodetic that are available for a few of the local datums) and consistent in definition with each other and also with the WGS 84 geoid worldwide.

Table 3
Transformation Parameters
—Local Geodetic Systems to WGS 84—
(For Complete Table—See Reference 4.)

Local Geodetic Systems*	Reference Ellipsoids and Parameter Differences**			Number of Doppler Stations Used to Determine Transformation Parameters	Transformation Parameters**		
	Name	Δa(m)	Δf × 10^4		ΔX(m)	ΔY(m)	ΔZ(m)
PROVISIONAL SOUTH AMERICAN 1956	International	−251	−0.14192702				
Mean Value (Bolivia, Chile, Colombia, Ecuador, Guyana, Peru, and Venezuela)				63	−288	175	−376
PUERTO RICO	Clarke 1866	−69.4	−0.37264639				
Puerto Rico and Virgin Islands				11	11	72	−101
QATAR NATIONAL	International	−251	−0.14192702				
Qatar				3	−128	−283	22
QORNOQ	International	−251	−0.14192702				
South Greenland				2	164	138	−189
REUNION	International	−251	−0.14192702				
Mascarene Island				1	94	−948	−1262
ROME 1940	International	−251	−0.14192702				
Sardinia Island				1	−225	−65	9

* Geoid heights computed using spherical harmonic expansion and WGS 84 EGM coefficient set (n = m = 180), then referenced to the ellipsoid and orientation associated with each of the local geodetic systems.

** WGS 84 minus local geodetic system.

Table 3 provides a sample listing of the transformation parameters between the 83 local datums and the WGS 84; a full listing is available elsewhere.[4]

In addition to the 83 local datums related to the WGS 84 through Doppler ties to the local control, transformation parameters (based on non-Doppler information) are also available for seven additional local datums.[4]

Accuracy

The accuracy of the WGS 84 coordinates of a site is significantly influenced by the method used to determine the coordinates. Table 4 lists the four methods generally available to establish the coordinate of a WGS 84 site and the associated accuracies achievable through each of the methods.

From Table 4, it is noticed that Method 1 (where a WGS 84 site is established through direct satellite observational data) gives the most accurate positional fix of 1-2 meters. Method 4 (the least accurate) is entirely dependent on the local/regional distortion of the local geodetic datum.

Table 4
Methods of Determining and Accuracy of WGS 84 Coordinates

Method of Determining WGS 84 Coordinates	Achievable Accuracies (1 σ)	
1. Directly Established in WGS 84 Coordinate System via a Satellite Point Positioning Solution	Φ and H	± 1 m ± 1 to 2 m
2. By Transformation from Doppler (NSWC 9Z-2) Coordinates by Bias Removal	Φ and H	± 2 m ± 2 to 3 m
3. By Transformation of WGS 72 Coordinates:		
(a) At Doppler Sites	Same as 2., Above	
(b) At non-Doppler Sites where WGS 72 Coordinates were Obtained *Indirectly* from Local Datums	Dependent on the Originating Local Datum Coordinates and Transformation Errors*	
4. By Transformation of Local Datum Coordinates	Same as 3.(b) Above	

* See DMA TR 8350.2-A, 1 December 1987.

of 1-2 meters. Method 4 (the least accurate) is entirely dependent on the local/ regional distortion of the local geodetic datum.

References

1. B.I.H., "Bureau International de l'Heure Annual Report for 1984," Paris, France, 1984.

2. Moritz, H., "Geodetic Reference System 1980," Bulletin Geodesique, 54(3):00-00, 1980.

3. Department of Defense World Geodetic System 1984, Its Definition and Relationships with Local Geodetic Systems; DMA TR 8350.2, Washington, DC, 30 September 1987.

4. Supplement to U.S. Department of Defense World Geodetic System 1984 Technical Report; Part II-Parameters, Formulas, and Graphics for the Practical Application of WGS 84; DMA TR 8350.2-B, Washington, DC, 1 December 1987.

UNITED
NATIONS

E

Economic and Social Council

Distr.
LIMITED

E/CONF.83/L.32
18 January 1991

ENGLISH ONLY

TWELFTH UNITED NATIONS REGIONAL
CARTOGRAPHIC CONFERENCE FOR
ASIA AND THE PACIFIC
Bangkok, 20-28 February 1991
Item 7 (e) of the provisional agenda*

CARTOGRAPHIC DATA RETRIEVAL, ANALYSIS, DEPICTION, PRESENTATION AND PRODUCT GENERATION: SPECIFICATIONS AND STANDARDS

Approaches to spatial data base transfer standards

Submitted by the International Cartographic Association**

---

* E/CONF.83/1.

** Prepared by Harold Moellering, Department of Geography, Ohio State University, Columbus, Ohio, United States of America.

91-01751 2244b (E)

/...

INTRODUCTION

Since the middle of the 1960's various individuals, groups and organizations in many countries in the world have been building various kinds of cartographic databases to use with their cartographic software systems to analyze and display their data. In the early years this work was uncoordinated and somewhat haphazard, but as the years progressed it came to be realized that great efficiencies could be gained if the cartographic database built by one group could be used by another on a system that is different from the originating system. It has been further realized that more efficiencies could be gained if transfer standards could be developed that would facilitate transfers of cartographic databases.

This idea has arisen in many cartographic and spatial data processing groups and organizations in the 1980's where groups have been working on this problem for some years. Other groups and organizations have become interested in the challenge of this problem more recently. As this work was initiated in various countries, research workers began to informally compare notes and experiences concerning such developments. A number of informal discussions have been held at the last few International Cartographic Association technical meetings. During the ICA congress in Morelia, Mexico, in 1987 under the Commission on Advanced Technology under the leadership of Dr. Eric Anderson, the topic was formally examined and discussed.

From those meetings the ICA Working Group on Digital Cartographic Database Exchange Standards was founded in early 1989 by Prof. Harold Moellering of the U.S.A. The following goals were established by Prof. Moellering for the Working Group (WG):

1) The WG will be organized in the 1989 time period;

2) The initial meeting of the WG will be held at the ICA meetings in Budapest in August, 1989.

3) To exchange information and reports by the ICA member countries concerning the development of digital cartographic data exchange standards;

4) To collect and distribute in the WG copies of all standards published in ICA countries;

5) To serve as a focal point of information concerning digital cartographic data exchange developments throughout the world;

6) To identify research needs that arise from the standards process;

7) A presentation by each member of the WG will be made at the Budapest meetings concerning cartographic standards activities in his/her member country.

An effort was made to contact the ICA countries that were engaged in or interested in such work to nominate a member for the WG. International organizations that were known to be working on this problem were invited to nominate an observer to the WG. The idea was to have a member or observer to represent each active ICA nation and international organization in the world.

The founding meeting of the Working Group was held at the ICA technical meetings in Budapest, Hungary in August, 1989. Representatives from 16 ICA countries were present for this meeting. At this meeting many WG members gave presentations concerning the status of cartographic database transfer standards in their country. At this meeting in Budapest, the WG also added an eighth goal, that of producing an ICA monograph that discusses the present state of development of such standards in the various ICA countries and organizations throughout the world. That desire has resulted in this monograph coming into existence. Since the meetings in Budapest the members of the Working Group have been working diligently to produce their chapters. The WG met in Switzerland in July, 1990 to review their draft chapters and to do the final polishing on them. You see the results of their diligent efforts before you.

This monograph is organized into an introduction by the editor that provides the background for this effort. It also provides an explanation of some of the important concepts that underlie this effort, as well as a discussion of the transfer process itself. This preliminary material is important to the reader can more clearly understand the individual standards efforts. This introduction also contains a brief review of each following chapter to succinctly encapsules each effort in a larger context. It concludes with a brief summary of this introductory material. Following that are about 20 substantive chapters that presents the efforts going on in each country and organization represented. This presents a comprehensive picture of the cartographic database transfer standards development efforts that are active throughout the world. In one or two cases groups invited to write chapters did not complete them.

As one reads these individual descriptions of the activities of

these standards developments in the ICA countries and other organizations, it is possible to get the impression that all of the theoretical details are completely understood. This is far from the case. Rather there are many theoretical concepts that are incompletely understood or in some cases, not well at all. These situations provide a number of interesting research opportunities, as described in Moellering (1991b).

BASIC CONCEPTS

In order to efficiently understand the transfer process and following discussions, it is crucial to clearly comprehend the fundamental cartographic theory that underlies this work. They are the notions of real and virtual maps, deep and surface cartographic structure, and the notion of cartographic data levels. These concepts, and many others, are emerging from the developing area of analytical cartography, which is major thrust to develop a more theoretical and mathematical basis for cartographic concepts. A brief review of analytical cartography has recently been written by Moellering (1991a).

The first major concept of interest here is that of real and virtual maps. During the early 1970's there arose many cartographic products such as CRT images and digital terrain models that went beyond the conventional definition of a map as a fixed hard copy product. These developments resulted in calls to expand the definition of what constituted a map. This dilemma was crystallized by Morrison (1974) in the lead article of the first issue of the American Cartographer where he recognized this growing problem and called for an expanded definition of what constitutes a map. Moellering was faced with the same problem and took up the challenge issued by Morrison. After a few years of research the concept of real and virtual maps was proposed (Moellering, 1980).

It turns out that there are two crucial characteristics that differentiate conventional hard copy maps from other kinds of virtual maps. The first is whether the product can be directly viewed as a cartographic image. Conventional maps and CRT images can be seen that way, but cartographic data files and things like Fourier transforms cannot. They must be transformed to a state that has direct viewability first. The second crucial characteristic is whether the product has a permanent tangible reality. Figure 1 shows a four class diagram that shows the resulting classes of real and virtual maps that are generated by yes/no answers to the two characteristics. The definitions for these classes (Moellering, 1980) are as follows:

> Real Map - is any cartographic product which has a directly viewable cartographic image and has a permanent tangible reality (hard copy). There is no differentiation as to whether that real map was produced by mechanical, electronic means.

PERMANENT TANGIBLE REALITY	DIRECTLY VIEWABLE AS A CARTOGRAPHIC IMAGE: YES	DIRECTLY VIEWABLE AS A CARTOGRAPHIC IMAGE: NO
YES	**REAL MAP** Conventional Sheet Map Globe Orthophoto Map Machine Drawn Map Computer Output Microfilm Block Diagram Plastic Relief Model	**VIRTUAL MAP-TYPE 2** Traditional Field Data Gazeteer Anaglyph Film Animation Hologram(stored) Fourier Transform(stored) Laser Disk Data
NO	**VIRTUAL MAP-TYPE 1** CRT Map Image a) refresh b) storage tube c) plasma panel Cognitive Map (two-dimensional image)	**VIRTUAL MAP-TYPE 3** Digital Memory(data) Magnetic Disk or Tape(data) Video Animation Digital Terrain Model Cognitive Map (relational geographic information)

Figure 1. The Four Classes of Real and Virtual Maps

Virtual Map - Type I - has a directly viewable cartographic image but only a transient reality as has a CRT map image. This is what Riffe called a temporary map. Given the direction of current scientific work, electrocognitive displays may be possible.

Virtual Map - Type II - has a permanent tangible reality, but cannot be directly viewed as a cartographic image. There are all hard copy media, but in all cases these products must be processed further to be made viewable. It is interesting to note that the film animation adds a temporal dimension to the cartographic information.

Virtual Map - Type III - has neither of the characteristics of the earlier classes, but can be converted into a real map as readily as the other two classes of virtual maps. Computer-based information in this form is usually very easily manipulated.

Here it can be seen that conventional cartographic products such as sheet maps, atlases, and globes that have a fixed tangible reality, and are directly viewable as a cartographic image are called Real Maps. The other three classes lack one or both of the two characteristics and are called Virtual Maps. These three classes provide for the expanded definition of maps that reflects many of the developments in modern cartography. It turns out that Virtual Maps can contain the same information as a Real Map, and in the case of a cartographic database, perhaps more. Moellering recognized that even cartographic databases should be considered maps because they can contain the information of a Real Map and can be transformed into one if necessary. This solution solves the dilemma recognized by Morrison.

It turns out that the information in these various classes of Real and Virtual Maps can be transformed from one to another as shown in Figure 2.

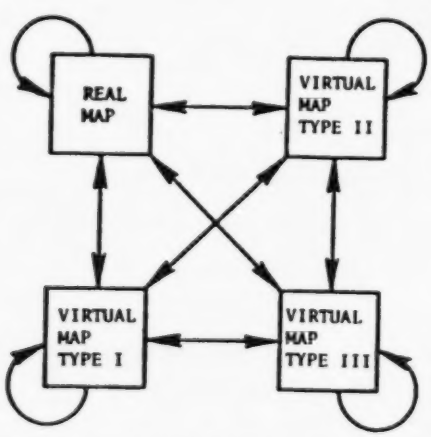

Figure 2. The 16 Real/Virtual Map Transformations

Expanding on a notion pioneered by Tobler (1979), transformations between the four classes of Real and Virtual Maps can be used to define all of the important data processes in cartography. As shown in Moellering (1984) these 16 transformations define operations such as digitizing (R --> V3), CRT display (V3 --> V1), making a CRT hard copy (V1 --> R), direct plotting (V3 --> R), or data base transfer (V3 --> V3). These transformations can also be used to design cartographic systems (Moellering, 1983) and can also be used to define the field of cartography itself (Moellering, 1987).

The second major concept is that of deep/surface cartographic structure developed by Nyerges in his dissertation (1980). Surface structure is defined as the graphic realization of cartographic information and when realized in a fixed hard copy form is called a Real Map. Following the precepts of Noam Chomsky in structural linguistics, Nyerges realized that there was a direct spatial analog to the linguistic deep structure. Cartographic deep structure is the set of spatial entities, attributes and relationships between them that may or may not be graphically realizable. This information is always in a virtual state and is usually found in Virtual Map Type 3 databases. Figure 3 shows this relationship graphically where the lower part of the figure, the surface

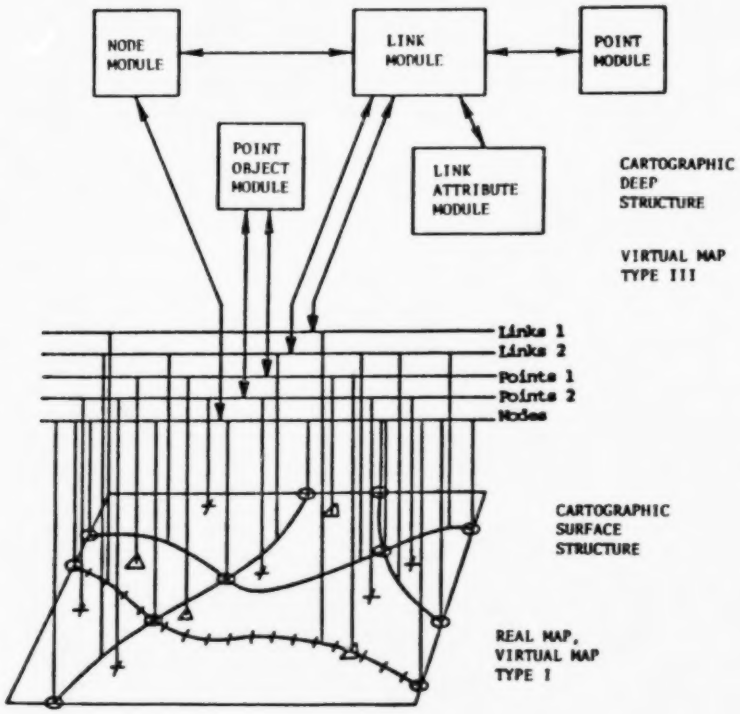

Figure 3. Deep and Surface Cartographic Structure

structure made up of Real Maps and Virtual Maps Type 1, is the area where traditional cartography has been focused for the many centuries of its long and glorious history. However, in the last decade, a new area has been identified, deep structure made up of Virtual Maps Type 3, that is now the focus of an expanding area of analytical work. Deep structure contains work on spatial data structures, analytical operators, fractals just to name a few. For a fuller discussion of analytical map use, see Nyerges (1991). This concept is introduced here because cartographic database transfers are really Virtual Map Type 3 deep structure transfers. More explanation and discussion will follow in a later section.

This concept greatly expands our understanding of cartography and directly reinforces the concept of virtual maps. It can also be seen that analytical cartography largely operates in the area of deep structure and displays its results in a surface representation of some kind, many times in the form of Virtual Map Type 1 CRT images.

The third major concept of importance here is that of Nyerges data levels (1980) which define the levels of spatial data from the most general level of Data Reality to the most specific level of Machine Storage as the bits and bytes are contained in computer hardware systems. The following table lists these levels and provides a short description of them.

Table 1. Nyerges Data Levels

1) Data Reality - The real world and data pertaining to it concerning cartographic entities and relationships between them.

2) Information Structure - A formal model that specifies the organization of information pertaining to a specific phenomenon. It includes data classes and relationships between them and acts as a skeleton for the canonical structure.

3) Canonical Structure - A data model representing the inherent structure of a data set which is independent of specific applications and systems which manage such data.

4) Data Structure - A logical data organization designed for a particular system in which specific relationships and links are implemented.

5) Storage Structure - A specification of how a particular data structure is stored in data records in a particular system.

6) Machine Encoding - The physical representation of how the structure is held in the physical devices of computer system hardware.

It turns out that early developments in cartographic data structures many researchers tried to define the Data Structure, Nyerges

Level 4, directly without having defined the more general levels of the Information Structure and the Canonical Structure first. The Information Structure is a formal model of the information to be housed and managed in the spatial database, while the Canonical Structure is a model of the data to be coded, structured and housed in the database. The Data Structure is dependent on those two more general levels if it is to be efficiently defined. The Data Structure is then stored in data records in the Storage Structure which is physically stored as bits and bytes in the computer hardware in Nyerges Level 6. This work suggests why so many spatial data structures of the 1970's did not work very efficiently or in some cases failed outright. Hence, this concept is crucial to understand in order to clearly see what is involved in the cartographic database transfer process.

THE DATABASE TRANSFER PROCESS

At the outset, one might conceive of this cartographic database transfer process as capturing and moving a Real Map image from one system to another. In this view such a transfer would be a surface structure transfer. However, the cartographic world is a far richer place than that. The cartographic information to be transferred must first be organized into a Virtual 3 deep structure database. This is because such a Virtual 3 deep structure organization allows for the addition of more deep structure information which is associated with the database, but is not of a surface structure (graphic) nature. Such deep structure information can include a wealth of attribute information, for example, that may be used in the database for analytical purposes and not necessarily for graphic rendering. The key idea here is that such a database transfer between systems is a deep structure Virtual 3 transfer and not a surface structure transfer. A deep structure transfer facilitates building the transfer file itself as well as the restructuring of the data itself into the spatial data structure of the system to which the database is being transferred. One must realize that when cartographic or spatial data is in a Virtual 3 deep structure form, it is much more flexible and manipulable than it would be in other states.

At this point it is important to understand the difference between the use of pairwise converters for database transfers, the current situation, and the use of a more general metafile transfer, the proposed situation for most national transfer standards. One issue involves the number of database converters that would be required to do the job. Suppose that there are 100 cartographic systems with heterogeneous data structures, software systems and hardware architectures in an open systems environment that are candidates for transferring spatial databases among them. Using the current situation of pairwise data converters as an example one would need

$$\frac{n(n-1)}{2} = \frac{100(99)}{2} = \frac{9{,}900}{2} = 4{,}950$$ pairwise converters

to accomplish the transfer between all combinations of systems. The desired situation is to have a common metafile transfer

standard that can be used for (almost) all database transfers where 2 n + = 2 (100) = 200+ metafile converters would be required to accomplish the task. It can be clearly seen that the metafile transfer approach is preferred because in theory about 200 metafile converters would be required, whereas 4,950 pairwise converters would be required. This is a tremendous difference. In practice this difference would probably be smaller because in the pairwise case not all combinations would require implementation, and in the metafile case converters would probably be required for general classes of spatial database systems. But even if three times more metafile converters were required, 600 in this example, and only 60 percent of the pairwise converters were required, the difference would be about 3,000 converters for the pairwise case and 600 for the metafile case. This is still a five to one savings for the metafile approach. That is why national standards groups are moving towards this solution for their database transfer requirements. For the long run, the metafile approach is clearly preferred.

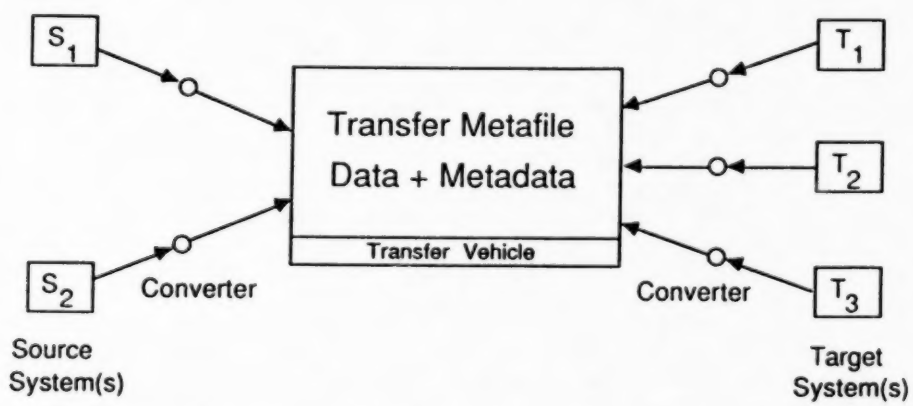

Figure 4. The Cartographic Database Transfer Process

Figure 4 shows an illustration of the general cartographic database transfer process. On the left is the Source Database with its own information structure, canonical structure, and data structure, data elements and modules. On the right are several Target Databases to which one desires to transfer the cartographic database. These cartographic databases are associated with different systems that may have very different data structures and hardware architectures. Therefore the source data structure usually cannot be transferred directly between the two systems. It is usually necessary to take the source database and convert it into the organization of the Transfer Metafile. This conversion is done by a software converter designed for that purpose that reads the data structure of the Source Database and converts it into the structure of the Transfer Metafile.

The Transfer Metafile has a structure that is specified by the national standard for which it was designed. This Transfer

Metafile is the actual vehicle that carries the data from the Source to the Target systems. The internal structure of various national transfer standards differ widely in approach and design. They range from fairly straightforward formats to fairly rich transfer mechanisms. This will be discussed later. Many national Transfer Metafiles have as their base an international transfer standard such as ISO 8211 or others to act as base transfer vehicle. This vehicle facilitates the actual mechanics of the transfer.

When the Transfer Metafile arrives at the Target System, it must be converted from the organization of the transfer file to that of the target system(s). This is accomplished by a converter that reads the Transfer Metafile and converts the structure of the data to that of the Target System. That system itself will then insert the actual data into its database.

One question that arises from the above description is what kinds of data components can be transferred with such a process. Fundamentally, one has descriptions of features from the real and attributes associated with them, cartographic objects that contain the geometry and topology of the features, information on the data quality, and other essential information such as projection, coordinate system, etc. The features have been defined by the individual national groups and code such things as mountains, streams, transportation, cities, soil, population and a host of other things that exist in the real world. Associated with these features are a set of attributes that contain information about those features such as mountain elevations, stream flow, transportation type, city name, soil type, population components, and so on. The cartographic objects usually have a set of primitives that begin with the level of spatial dimension, 0-, 1-, 2-, 3-, etc., and may contain information about topological properties of the object, such as connectivity or contiguity (neighbor relation). Quality information that relates to the above features, attributes and objects is specified and carried along with the transfer. Depending on how this information is specified, this quality information could relate to large classes of data, or to individual features or objects themselves. Ancillary information such as projection, coordinate system is usually part of the transfer file and serves an important role in processing the data. Finally, some standards include metadata, which is data that relates to the substantive data being transferred, to aid in the transfer process. Such metadata can be particularly helpful to the decoding converter that receives the Transfer Metafile and converts into the structure of the Target System. The nature of this metadata varies greatly between the various national transfer standards. This above discussion also implies that each national standard has specified things like feature definitions, object definitions, quality levels, and the Transfer Metafile organization itself.

The Transfer Process and Data Models

The database transfer process can also be examined from the point of view of the data model(s) involved. At the conceptual level it

involves the Information Structure, Nyerges level 2, and the Canonical Structure, Nyerges level 3, while at the operational level it involves the Data Structure, Nyerges level 4 and the Storage Structure, Nyerges level 4. The Information Structure is a model that describes how the entities from the real world that are contained in the database are related one to another. In order for a database transfer to take place effectively, the source database and the target database must be compatible with one another. For example, if the source database only contains information pertaining to roadway systems and the target database only information pertaining to streams and waterways, a data transfer is not feasible because the source and target databases are not compatible with each other. If, on the other hand, the target database contains data on streams, waterways, roadways, and communication linkages, then a transfer from the source to the target database is feasible. Therefore, at the information structure level, when the subject matter of the source and target databases is compatible, a transfer between them is usually feasible, assuming that the lower Nyerges levels are compatible too.

One can now look at the Canonical Structure, Nyerges level 3, which specifies the model of the <u>data</u> that is contained in a database. At the outset one must be clearly aware that there are three general families of data structures that are specified by such data models. They are vector, raster and relational. These are treated as distinct classes of data organization which are not compatible with one another. Therefore, it is not feasible to attempt to transfer data from a source database that has some sort of raster structure to a target database that has some sort of vector structure. Going between these three families of spatial data organization is a data conversion problem beyond the sort of spatial data transfer problem being discussed here. Since this discussion focuses on the data transfer question, such conversions between the three families of spatial data will not be further considered here. It is therefore assumed that database transfers of the kind being discussed here will be transfers <u>within</u> each of these three fundamental families of spatial data. However, with some of the national efforts, it is possible and feasible to transfer data from these three families within different sections of a transfer file. In that case raster data from the source system would arrive as raster data at the target system, vector from the source system would arrive at the target system as vector data, and so on. No conversions between families could be made. The intriguing question as to whether there may exist a unified theory of spatial data that would permit more general data models and structures has been raised and discussed in Moellering (1991b).

The data model specifies the formal organization of the spatial data for a particular system. When transferring data between two systems that have the identical data model, even when there are differences in the implementation of the Data Structure, Nyerges level 4, the transfer is straightforward. This current discussion is setting aside the question of hardware architecture differences

for the moment, which will be discussed later. The more typical case is when the data models in the source and target systems are different, even though they are in the same data structure family. The general answer to this question is that if the source and target systems contain the equivalent information, even though it may be structured in differing data models, a data transfer can usually be carried out. However, there are limitations to this possibility. For example, if the source system data model contains geometry and topology for the fundamental cartographic objects, and the target system data model only contains geometry for such objects, the transfer can be made, although it will be an information losing transfer. However, if the source system data model only contains geometric information on the cartographic objects, and the target system data model contains both geometry and topology, then a problem arises because the target system requires information that is not found in the source system. Since the data transfer tools described below are not designed to generate new information for the target system, such a transfer cannot be carried out. Therefore, the general principle to be learned here is that these kinds of data transfers can be information losing, although it is inefficient to do so, but they cannot be information gaining.

One can then consider the specifics of the Data Structure, Nyerges level 4. It is very common for large differences to exist between Data Structures in the source and target systems even though the data models may be fairly similar. Obviously large differences will exist between the two Data Structures when the data models are also very different. Assuming that the information contained in the source and target systems are equivalent, the transfer process must restructure the data so it is compatible with the target system when they arrive at that end of the process. The transfer process must also overcome differences at the Storage Structure level, Nyerges level 5, as well. There will almost always be large differences between the Storage Structures of the source and target systems due to differences of the operating system and hardware architecture differences. These kinds of differences are not inconsequential and must be properly handled by the transfer process.

Transfer Machinery

One can now begin to turn to the machinery that actually carries out the data transfer. It turns out that the various national standard proposals differ considerably in approach and outlook to this problem. This section provides a conceptual framework of the range of the kinds of transfer machinery that is being proposed in the field. In all cases such transfer machinery must accomplish two major tasks:

1) It must transfer spatial data from source to target system where there are differences between the data models, data structures, and storage structures of the two systems, as discussed above;

2) It must transfer the spatial data in such a way that the process transcends differences in hardware architecture between the source and target systems.

This second requirement is just as important as the first. Every transfer standard must address this question. In general, approaches to the problem range from using a fairly fixed format to using one of the international standards such as ISO 8211 or EDIFACT as a basic implementation vehicle.

Reflecting back to Figure 4, every standard has a transfer file. Those that are more rigid transfer the information in the form of a fairly rigid data model. As the transfer standard becomes more flexible the data model reflected in the transfer file becomes more flexible. The most flexible form of transfer standard can be called a transfer mechanism. Here the transfer data model is a very flexible minimal model that can accommodate a wide range of source/target data models. This range of approaches to the problem can be conceptually viewed as a continuum as illustrated in Figure 5. At the extreme left one has the system specific fixed data

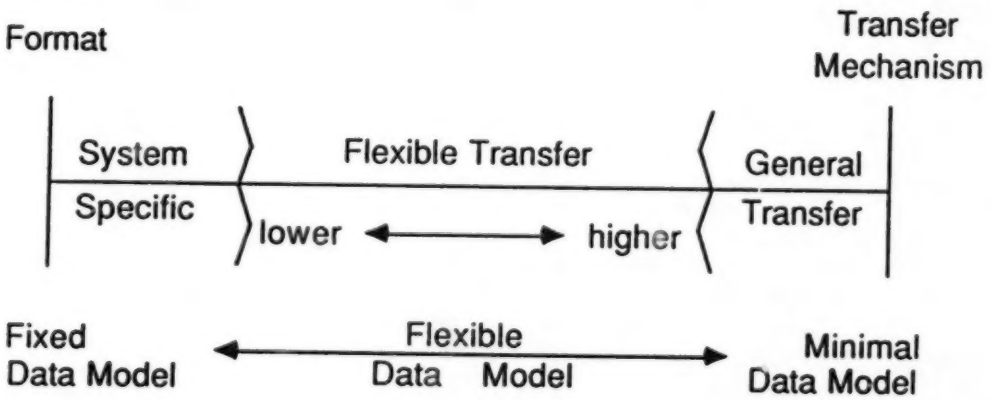

Figure 5. The Range of Cartographic Database Transfer Processes

model that would be a fixed fairly rigid format. If the source and target systems were the same fixed data model used by the transfer standard, the data transfer would be very simple. However, this level is very inflexible can generally cannot accommodate a wide range of other data models for transfer. It would have fairly limited use between differing systems. Few if any of the national standards proposals are this rigid. More likely is the case where the transfer standard has a its own fairly specific data model that has been designed to accommodate a wider range to source and target data models. These more flexible data formats are more widely applicable to the situation where there are wider differences between the source and target data models. These systems require that the source data model be converted into the transfer data model which is then later converted into the target system data model. This also implies conversions in the data structures and file structures

as well. The more flexible is one of these transfer formats, the wider range of source and target data models that can be accommodated. However, this implies increasing complexity of the standard as the flexibility of the format increases. The most flexible kind of a transfer standard tends toward a very flexible data model that is almost minimal in nature. It focuses on a modular primitive object design where the transfer structure is organized around the source data model in such as way that the transfer structure can be decomposed and reconstituted later as the target data model. This sort of transfer standard can be called a transfer mechanism. At the extreme such a transfer mechanism would have a very minimal data model that can be structured to accommodate an extremely wide range of source/target data models. As the range of the flexibility of such a transfer mechanism increases, the complexity of the mechanism would also increase as well. The goals here would to design a mechanism that maximizes flexibility and minimized complexity. Since these goals conflict and are tradeoffs one with another, the task of designing a national transfer standard that serves the professional community efficiently is not an easy one.

DESIRED CHARACTERISTICS OF THE TRANSFER PROCESS

As one looks at this sort of spatial data transfer process, it is possible to identify basic characteristics that such a process should possess. The following discussion provides a listing and brief definition of the desirable characteristics that such a process should have. It is based on an earlier discussion by Moellering (1988) and has been adapted to the more general international situation. The discussion will be carried out in terms of general characteristics, cartographic objects, data quality, cartographic entities, and finally the transfer machinery.

Transfer Three Major Families of Spatial Data Structures

Currently there exist three major families of spatial data structures. A successful database exchange process should be able to transfer vector, raster and relational data structures and associated ancillary information.

Transfer Across Different Computer Architectures

For proprietary reasons there are many different kinds of internal machine architectures for computers. Many of these architectures are not compatible with each other. A good spatial database transfer mechanism will be able to transcend such architectural differences.

Transfer Databases Between Noncommunicating Parties

Typical database exchanges require prior communication, documentation and sometimes extensive discussion before any data can be transferred. The goal is to specify the standard such that this kind of communication is not necessary, but is built in as part of a standard data exchange mechanism.

Modular and Extendible
Because of the dynamic developments in the field of cartography and spatial data structures, the standard must be specified in a modular fashion. In this way new developments which need to be included in the future can be added in a modular fashion without disturbing other parts of the standard. Obsolete parts could be deleted in a similar way.

Robust and Reliable
Any database exchange mechanism must be specified such that it is robust and reliable. This means that it must not be sensitive to some data errors and occasional data corruption such that data perishability during transmission should be very low, thus insuring that the probability of correct transmission is quite high.

Media Independent
The exchange mechanism should be media independent such that spatial databases can be transferred by magnetic tape, direct telecommunication, hard or floppy disk, CD/ROM or any other appropriate medium.

Transfer Both Syntax and Semantics
A good transfer process with the above characteristics should be able to exchange the syntax, or structure of the data reasonably straightforwardly. However, the capture of the semantics, or meaning of the information transferred is much more difficult to insure. Transfer of the semantics is more difficult to do than is the transfer of syntax.

Facilitate the Transfer of Self-Describing Databases
Currently such databases are experimental or only a gleam in the designer's eye. However, it is clear that such databases are being developed and that they will be in common use within a decade. A standard must accommodate such exchanges.

Use Best Concepts and Existing Standards Available
Developing an efficient and comprehensive spatial database transfer standard in not a simple matter. Therefore one must be clearly aware of current research such that the best available concepts are used in the design of the standard. The items presented in the conceptual background form the crucial intellectual basis of a standard. Existing national and international standards that apply to the problem must be sought out and examined. Such existing standards should be utilized whenever possible.

Awareness of Work in cognate Areas
Every discipline such as cartography has interactions with its cognate areas, and therefore one must be aware of what is going on in those areas in the way of standards activities. In this case one must pay attention to four primary cognate areas: geographic and land information systems, photogrammetry and remote sensing, computer graphics and CAD/CAM, and, geodetic and land surveying.

Involve the User Community in the Process
This is a very important and time consuming activity. However, it is crucial because as the scientific solution to the standard is developed, a consensus must be developed in the professional community it is intended to serve.

Maintenance Authority
Developing cartographic standards is NOT a one time process. Since such a standard is being built in an area such as spatial data, there is active research taking place in many areas. One must realize that periodically the standard will have to be updated in the future. Therefore, it is clear that the initial effort must be conducted such that future enhancements can be made without disturbing the existing parts of the standard. Hence, the notions of modularity, extendibility and robustness become very important so that the standard can be enhanced as new developments take place. All of this implies the founding of a maintenance authority to supervise the interpretation of the standard and to lead the work of actual maintenance. It is expected that the area with the highest demands on maintenance will be the cartographic entities.

CARTOGRAPHIC OBJECTS

Cartographic objects are the digital representation of entities and as such are the fundamental building blocks of any spatial data structure. Hence, they must be modular, and be capable of being assembled into more complex and higher dimensional structures.

Only Necessary to Define Primitive and Simple Objects
As with any standard, one must always clearly define the primitives in the system. Here it was also necessary to define some simple objects that are constructed out of primitives from lower dimensions. These simple objects serve as the primitive objects for the higher dimensions.

0-, 1-, 2-, and 3- Dimensional Objects Should be Defined
All four levels of dimensional primitives should be specified with provisions for building higher level objects if they become necessary. The standards currently do not explicitly define anything above 2-D primitives because not enough is known about them at the present time. 3-D and higher dimensional objects can be added as a future enhancement as they are better understood and needed by the community.

Geometry and Topology
When defining cartographic objects, it is necessary to define them so they include aspects of geometry and topology. How this is done can vary greatly depending the nature of the particular national standard being defined.

Coordinate Systems
For a spatial data standard objects must be validly defined for both Euclidean and simple curved surfaces such as the sphere and

the ellipsoid.

Modular and Extendible Object Set
Given the above object requirements and general characteristics it is clear that the set of primitive and simple objects must be modular such that new ones, 3-D for example, could be added in the future, and so that compound and complex objects can build out of them.

DATA QUALITY

Data quality is an essential ingredient to any database transfer because the integrity of the data must be insured throughout the exchange process.

Truth in Labeling
The fundamental rubric under which the data quality portion of the standard operates is truth in labeling. This means that the producer of the database should be required to provide specified quality information for review by the prospective user. The user would review the quality report and decide whether that particular database is suitable for a particular application. It is anticipated that the better quality databases will see more frequent use than those of lesser quality and hence the specification of the quality report will create a tendency towards creating databases with improved data quality.

Flexible Quality Levels
In order to function as a national standard with broad application, it is clear that a national must have flexible quality levels in it. Fixed quality levels are product specific and therefore outside of a national standard, but may exist as internal quality specifications for particular products produced by individual organizations.

Various Levels of Testing Rigor
Because of the flexible quality requirements that are necessary, there are also different levels of testing rigor that could be applied in a particular situation. However, the report should explicitly state which level has been applied and what the results are.

CARTOGRAPHIC ENTITIES

Cartographic entities exist in the real world and are the things being represented modeled, analyzed and displayed in modern cartographic work.

Universal Set of Entity Definitions
The set of entity definitions for a national standard are desired to be universal and encompass all entities that may be coded in spatial databases at the national level. However there is a bottom limit of interest in detail for a national standard. A standard should be designed with conceptual hooks on the bottom to which

additional entities and attributes could be attached.

Modular Entity Definitions
Entities are defined in a modular fashion with many aliases of analogous terms linked to them. This will serve to simplify the structural complexity of the definitions themselves, and pave the way for a nonheirarchical definition structure for the entities, if desired.

Extendible Set of Entities
Because of the modular definitions of the entities, a maintenance authority could update and modify the entity set as a regular and systematic part of its work.

Scale Independent These entity definitions are designed to be scale independent and not related to product specific scales. This is because a database may be used at a range of scales for various purposes, within reason.

Nonhierarchical Definition Structure
It is possible to define a set of entity definitions that are that are not hierarchically organized. Hierarchical entity definition structures are cumbersome to use, subject to judgmental error and are not very amenable to modern query retrieval systems. Therefore, an entity can be defined with many possible attributes and attribute values that could be assigned depending on the situation of the actual entity in the real world.

Designed for Modern Query Retrieval Systems
With the modular definitions, scale independence, and nonhierarchical definitional structure, entities, their associated attributes, and attribute values can be easily entered, retrieved and manipulated in modern database query management systems.

THE TRANSFER MACHINERY

The transfer machinery is what actually can convert the source data base to the transfer metafile form and later decode the metafile into the target database. The transfer metafile is the exchange file that is actually transferred between computer systems. This kind of transfer can occur with magnetic tape, by direct telecommunication, with hard or floppy disk, CD/ROM or almost any other kind of form because a standard should be media independent as pointed out earlier.

Transfer Three Families of Data and Ancillary Information
The data exchange mechanism should be designed to transfer data bases from all three of the fundamental data structure families: vector, raster, and relational, as well as information pertaining to attributes of the entities and associated quality information.

Modular Forms and Modules
Each of the three families of data structures should have a modular

transfer form associated with it. Each of these three forms should be composed of a set of modules that transfer the primitives, attributes, quality information, and other ancillary information. Every module of this kind is composed of a set of records that describe its own contents.

Preserve Syntax and Semantics
In the database transfer between systems, the syntax is preserved in the logical forms and modules. However, the semantics, or meaning, is implicitly preserved in the syntax of the exchange. Clearly, the syntax of the information is easier to preserve than the semantics.

Minimize External Documentation
A good database exchange process will reduce the need for external documentation, particularly if the software is written to run interactively. Ultimately, such a standard should be designed with the concept of being able to support self-describing databases in the future when they become available.

Generate Export Database Metafiles
The transfer converter processes the information from the source database and creates an exchange metafile for the actual database transfer between systems as shown in Figure 4. The transfer metafile will then be decoded into the target database by the converter.

Conform to Existing Standards
A particular standard must usually conform to existing national standards. In addition, International Standards Organization (ISO) standards should be used whenever practicable. These are the same or similar to existing standards used in other countries.

OVERVIEW OF STANDARDS EFFORTS

Currently there are about 20 ICA member nations and other international organizations working on the question of spatial database transfer standards. This work contains chapters that describe 18 of those efforts that are in progress. The range of these efforts includes those that are in the beginning stages of examining the problem to those that are nearly finished with a comprehensive effort. The following discussion summarizes each effort for which a written chapter has been received.

Australia
Work on a national topographic data transfer standard began in Australia in 1974, a very early effort. The effort focused on developing a transfer format for map data that was codified in 1981 as AS 2482 Interchange of Feature Coded Digital Mapping Data by Standards Australia. The standard was revised in 1984. In the later 1980's the group realized that a more comprehensive database transfer standard was needed. The groups are now evaluating their effort as well as the work of several of the ICA national groups.

Currently the U.S. Spatial Data Transfer Standard (SDTS) is a leading candidate for adoption. Further evaluation is proceeding.

Austria

Although digital map data processing has been going on for many years in Austria, it is only recently that an initial database transfer standard has been proposed by the Austrian Standards Institute. This standard is called ÖNORM A 2260, 1990 Datenschnittstelle für den Austausch geographisch-geometrischer Plandaten (Interface for digital exchange of geographic-geometrical data). This data transfer format is oriented primarily towards large scale maps and drawings. As such it currently geometry only with topology not explicitly specified. Since the standard was proposed in 1990, it has not yet been extensively field tested.

Canada

Canada is in the interesting position of developing more than one spatial database transfer standard, the first in the topographic area, and the second in the hydrographic area. The first effort began in the late 1970's by the Canadian Council of Surveying and Mapping (CCSM), now called the Canadian Council on Geomatics (COG). They have developed a Standard for the Exchange for the Exchange of Digital Topographic Data which was originally proposed in 1982. The proposed standard is a variation of a flexible format, and includes a data model, standard features and attributes, a quality specification, and a file format. Implementation and testing of the standard commenced in 1986. The standard is in its later stages of approval.

The second major effort in Canada is that of Map and Chart Data Interface Format (MACDIF) proposed by a group of agencies in the country. Work began in 1985 and is progressing. The MACDIF syntax is based on the Abstract Notation Syntax (ASN) and is intended "to standardize the interface point between two communicating entities regardless of the mapping or charting application".

Work is also going on to develop a Geographic Document Architecture (GDA). This effort is intended to operate is an Open Systems Interconnection (OSI) environment.

Peoples Republic of China

The challenge of cartographic database transfer is seen as a component of Geographic Information System (GIS) standardization in the Peoples Republic of China. Work is in the early stages of defining the problem in this context. It includes projects to develop land classification codes, creation of 1:4M geographic database, computerization of topographic symbols, among others.

Finland

Work on database transfer has been going on in Finland since the 1970's. In 1985 the Ministry of Agriculture and Forestry established a steering committee on the LIS project. The practical part of this work is being carried out by the National Land Survey. This work has resulted in National Administrative Standards (VHS) VHS

1041 on Geographical Data Representation and VHS 1040 on Message Description. These standards operate in an EDIFACT (ISO 9735, Electronic Data Interchange For Administration Commerce And Trade) environment. As such these data transfer standards seem to be a fairly flexible transfer mechanism. Additional work has been carried out on a Geographical Data Dictionary System (GDDS), a geographical query language that is a subset of SQL, as well as an EDIFACT interpreter.

France

Work on a national transfer standard in France was initiated by the National Council for Geographic Information (CNIG) in 1987. This led to a Commission for the Normalization of Exchange Formats. This group has been working on the database transfer standard in the areas of data model, data definition, exchange files, and exchange of messages. This has led to the adoption of the DIGEST data model (see DIGWG below) implemented on an ISO 8211 base that is called EDIGEO. Testing is in progress.

Federal Republic of Germany

The effort in the Federal Republic of Germany was begun in the early 1970's by the Working Committee of the Surveying and Mapping Institutes of the Länder (AdV). In 1982 the Uniform Database Interface (EDB) was published. This work has now become involved with the development of the Authoritative Topographic Kartographic Information System (ATKIS). As part of this work a data model, feature catalog and symbol catalog have been defined. As such EDBS appears to be a relatively fixed format. Current work is being carried out to define a more flexible version of EDBS in cooperation with other European efforts, notably CERCO.

Hungary

In the later part of the 1980's digital cartographic data processing became more widely spread and the need for a database transfer standard was realized. Initially efforts were made to review the Canadian, American, British and German standards proposals. Further work has resulted in a proposal for a Digital Cadastral Map standard (DCM). Work on this effort is continuing.

Japan

Although digital cartography has been used in Japan for many years, it is only relatively recently that standardization efforts have been actively pursued. In 1985 the Geographical Survey Institute formed the Committee for Digital Mapping Standardization. This group defined the Standard Procedure and Data Format for Digital Mapping in 1988. This specification includes data quality, a feature coding system, and transfer format. As such this transfer standard is a somewhat flexible format based on fixed length records.

New Zealand

In 1987 Land Information New Zealand (LINZ) began closely evaluating possible alternatives for a spatial database transfer standard. After careful study, the U.S. Spatial Data Transfer Standard (SDTS)

has become a leading candidate for adoption. However, LINZ is developing attribute definitions for use in the country. Further work is continuing.

Norway
In the late 1970's the Norwegian Ministry of Environment initiated the SOSI (Coordinated Approach to Spatial Information) project. From this project arose a defined transfer format, SOSI, in 1985. Object definitions and attribute codes were defined in 1987. The SOSI format is specified at four levels of use and as such is reasonably flexible. An ISO 8211 implementation vehicle is being considered. Currently SOSI only handles vector data, but future plans include handling raster and pictorial data.

South Africa
In 1985 a project team was formed at the CSIR Centre for Advanced Computing and Decision Support to develop a national spatial data exchange standard for South Africa. In 1987 SWISK 45 was published and has now become known as the National Exchange Standard (NES). NES provides for the transfer of vector and raster data. As such it is implemented by a relational transfer format that seems to be rather flexible. Current work on NES includes further enhancement of the standard and producing a user manual.

Sweden
In the early 1980's the Swedish Association of Local Authorities developed a simple standard, KF85, for the transfer of vector data. Since 1986 an effort has been under way by the Research & Development Council for Land Information Technology (ULI), to define a more comprehensive data transfer standard. Several Working Groups are carefully evaluating standards being developed in other countries. Currently, primary interest is focusing on an adaptation of the British NTF format on an ISO 8211 implementation that is compatible with the German ATKIS system in cooperation with CERCO.

Switzerland
The Swiss are currently developing a cadastral data system that will use a data transfer format called AVS (Amtliche Vermessungs Schnittstelle). They are also evaluating other national efforts to develop such data exchange standards. There is interest in the possibility of adapting one of these standards as it applies to the situation in Switzerland. Evaluations are continuing.

United Kingdom
In 1983 the House of Lords Select Committee on Science and Technology recommended that a set of map data exchange standards should be established to replace earlier, more limited work. In 1986 the first version of the National Transfer Format (NTF) was issued. It is a reasonably flexible format that can transfer vector data with both geometry and topology. Raster and grid data can also be accommodated. NTF is specified on 5 levels of operation and transfers information on features and data quality. Current work involves evaluating the possibility of using ISO 8211 as the base

implementation mechanism for NTF.

United States
The need to develop a comprehensive cartographic data transfer standard became evident in the early 1980's. To this end the ACSM National Committee for Digital Cartographic Data Standards was founded in 1982 under the sponsorship of the U.S. Geological Survey. Shortly thereafter the Federal Interagency Coordinating Committee for Digital Cartography was founded in 1983. Through their cooperative efforts The Proposed Standard of Digital Cartographic Data was published in 1988. Further work by the USGS Technical Review Board refined what is now known as the Spatial Data Transfer Standard (SDTS). SDTS is a very flexible exchange mechanism that will transfer vector, raster and relational data. Digital cartographic objects that have a wide variety of geometric and topological properties can be transferred. The standard consists of an object specification, entity specifications, data quality information, and the transfer mechanism. SDTS uses ISO 8211 as the basic implementation vehicle. SDTS has been extensively tested and is currently undergoing its final evaluation and polishing on its way to becoming a Federal Information Processing Standard (FIPS).

Comité Europeen des Responsable de la Cartographie Officielle
CERCO is an organization composed of the directors of the European national cartographic agencies. As such CERCO is interested in the possibility of defining a European Transfer Format (ETF). The leading contender seems to be a modification of the British NTF format adapted to an ISO 8211 implementation base. Discussions are continuing.

Digital Geographic Information Working Group
DGIWG is an international group with members of several European countries including the United States and Canada that was formed in 1983. Most of these countries are NATO members, although the DGIWG leadership has stated that this effort is independent of NATO. DGIWG has recently produced a proposal for a data transfer format called DIGEST, which is intended to handle raster, vector and matrix data. Digest is being amended to run on an ISO 8211 implementation base. A feature and Attribute Coding Catalog (FACC) has also been produced, along with several specifications for raster products. Field testing of DIGEST is continuing.

SUMMARY AND CONCLUSIONS

As the reader can see, there are currently many cartographic database transfer efforts going on in many parts of the world. The ICA Working Group on Cartographic Database Exchange Standards was founded in order to provide a forum for discussing this work at the international level.

In order to really understand the data transfer process, it is very important to understand the key concepts involved, such as real and

virtual maps, their transformations, deep and surface cartographic structure, and the six Nyerges data levels. With those basic concepts in hand, one can begin to more fully understand the database transfer process. It is clear that the transfer metafile approach has advantages over the conventional pairwise converter approach because of the dramatically fewer number of data converters that would be necessary to specify, build and maintain.

It can be seen that it is possible to design and build a variety of cartographic database transfer processes that range from a simple fixed format that has rather limited use, to a more flexible format that has a much wider scope of use, to an exchange mechanism that can transfer most data organizations within the three data structure families in an environment that is hardware independent. These characteristics, plus many more discussed above provide the specifications for an ideal spatial data transfer mechanism.

Finally, one can review the large number of national efforts to develop such standards as discussed in the following chapters of this monograph. It can be seen that there is a very wide range of activities going on from some groups that are evaluating the situation to groups that have been working on the problem for many years and are in the final stages of a major transfer standard effort.

The question can also be raised concerning the future of this work, and the Working Group specifically. Clearly there is much more work to be done to continue dialogue between these various groups as the work continues. It is also possible to begin work to make comparisons between the standards being developed and proposed. It is possible that commonalities between the various transfer standards can be identified with the possibility of developing interlinkages between some of them. The question of a world standard has been raised, but this kind of a goal seems very elusive indeed. It seems possible that some of the standards could be adopted on a regional basis for common benefit. However, much more effort is required before this question can be efficiently answered.

REFERENCES

Moellering, H., 1980, "Strategies of Real-Time Cartography", Cartographic Journal, 17(1), pp. 12 - 15.

_____, 1983, Designing Interactive Cartographic Systems Using the Concepts of Real and Virtual Maps", in Wellar (ed.), Vol. II, Proc. of the Sixth International Symposium on Automated Cartography, pp. 53 - 64.

_____, 1984, "Real Maps, Virtual Maps and Interactive Cartography", in G. Gaile and C. Wilmott, (eds.), Spatial Statistics and Models, Dordrecht: Reidel Publishing Co., pp. 109-131.

_____, 1987, "Understanding Modern Cartography Using the Concepts of Real and Virtual Maps", Prod. of the 13th International Cartographic Conference, Morelia, Mexico, Vol. 4, pp. 43 - 51.

_____, 1988, "Fundamental Concepts that Form the Basis of the Proposed American Cartographic Data Exchange Standard", Cartography, 17(2), pp. 9 - 14.

_____, 1991a, "Whither Analytical Cartography", Cartography and Geographic Information Systems, 18(1), in press.

_____, 1991b, "Research Issues Relating to the Development of Cartographic Database Transfer Standards", in, J-C. Müller (ed.), Cartographic Research Agenda in the 1990's, Elsevier, forthcoming.

Morrison, J.L., 1974, "Changing Philosophical-Technical Aspects of Thematic Cartography", American Cartographer, 1 (1), pp. 5 - 14.

Nyerges, T.L., 1980, Modeling the Structure of Cartographic Information for Query Processing, unpublished Ph. D. dissertation, Dept. of Geography, Ohio State University, 203 pp.

_____, 1991, "Analytical Map Use", Cartography and Geographic Information Systems, 18(1), in press.